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Method and device for a full-duplex-capable radio transmission system with CDMA access

INS A1

The invention relates to a method and a device for a full-duplex-capable radio transmission system with CDMA access, having a central radio base station and a plurality of subscriber stations which are independent of one another.

In the field of radio-supported information systems which operate with a central radio base station and a plurality of external stations or subscriber stations which are independent of one another and which permit information to be transmitted in full duplex form in both directions, the information in the downlink which is intended for the individual users is frequently multiplexed into a telecommunications channel and transmitted organized as an access system in the uplink. Examples of such systems are mobile radio systems, public trunked mobile radio systems, point-to-multipoint microwave radio systems and wireless local loop systems. Orthogonal signal domains which differ from one another are used in each case for the multiplexing or multiple access, these signal domains being, for example,

- frequency division multiplex or access systems FDMA (frequency division multiple access)
- time division multiplex or access systems TDMA (time division multiple access)
- code division multiplex or access systems CDMA (code division multiple access) or SSMA (spread spectrum multiple access)
- space-division multiplex or access systems.

The systems differ in that the transmission of information from and to the individual users takes place in separate frequency, time, code or spatial segment positions. Interleaved, coupled or respectively different multiplex and access technologies within one system, so-called hybrid methods, have become known. Depending on the use and implementation, different transmission

parameters and transmission quality criteria can be obtained with these methods.

In CDMA systems, the user signal is coded by gating it with a spread function using logic operations, a separate spread function which is orthogonal to the other spread functions being selected for each subscriber station. The logic operation is carried out here in each case by means of an X-OR gate, for example. At the receiver end, the coded signal can be demodulated through knowledge of the associated spread function, the coded user data for other subscriber stations becoming zero during the demodulation process owing to the orthogonality. It is particularly advantageous with CDMA systems that all the users can operate in the same frequency band and a relatively high degree of interference power in the band can be tolerated. Furthermore, under certain conditions it is possible that adjacent radio cells can operate on the same frequency band. It is generally a disadvantage that the multi-user interference, which arises in practice as a result of implementation problems such as band limitation, level differences between the individual transmissions, multi-path propagation etc. and which leads to a loss of orthogonality. In the radio systems under consideration, it is to be noted basically that because of the different signal transmit times owing to different distances between the external stations and the central station an asynchronous reception situation is normally produced in the base station receiver, which situation considerably aggravates this interference to such an extent that under ideal conditions code orthogonality is then no longer produced in the uplink. In this case, the maximum number of simultaneous transmissions M within a frequency band in the uplink of, by approximation, a DS-CDMA system can be estimated as follows:

$$M = PG/(E_b/N_0),$$

PG being the process gain or spread factor and E_b/N_0 being the ratio of bit energy to interference power, necessary for the aimed-at bit error rate, at the demodulator. The spread factor is the ratio of t_{bit} to t_{chip} and is typically between 10^1 and 10^4.

Assuming the ratio E_b/N_0 is, for example, 3, which corresponds to approximately 5 dB, only approximately 1/3 of the transmission capacity, based on the same bandwidth being seized, is available in the uplink in comparison with the downlink or in comparison with TDMA or FDMA systems if orthogonal signals are assumed for the latter.

Sub A2 Various methods are known which reduce the previously described disadvantage of the asynchronous CDMA methods, for example the synchronization of the external station in such a way that its transmission can be processed in synchronism with the chip in the receiver of the base station. In addition, it has been proposed to implement interference concelers which, by means of mathematical algorithms, subsequently eliminate the interference component of the parallel transmissions on the basis of different a priori or a posteriori knowledge. Furthermore, it has also been proposed to use multi-user detectors. A disadvantage of all these known methods is that they are very costly to implement.

INS A3

The invention is therefore based on the technical problem of providing a method and a device for synchronization in a radio transmission system with CDMA access, by means of which method and device the multi-user interference in the radio base station in the uplink mode can be reduced with low cost in terms of implementation.

Sub A4 The technical problem is solved by means of the features of patent claims 1 and 9. It is necessary for the radio transmission system to be operating in time division duplex mode in which transmission and reception are separated from one another in terms of time within one telecommunications channel, which significantly simplifies the sequence control. In order

~~to synchronize all the subscriber stations, the radio base station transmits a maximum sequence or gold sequence, specific to the radio transmission system, in the form of a preamble for all the subscriber stations before the actual data transmission. Since the information on the direct subscriber-specific system control, such as, for example, call setup and the like is transmitted in a central service channel, a common preamble can be used for all the subscriber stations. This preamble can be detected without restricting other system parameters with a significantly better signal/noise ratio, since multi-user interference is not present and the subscriber-specific signal powers can be transmitted in an additive, coherent fashion, which brings about a high level of detection reliability in the subscriber stations. The preamble which is received there is fed to a matched or correlation filter whose output signal serves as a trigger criterion when a defined amplitude threshold value is exceeded. Further advantageous refinements of the invention emerge from the subclaims.~~

The averaging over time of the synchronous information which is determined, and the evaluation of the knowledge of the precise value between two successive preambles, makes it possible to achieve substantially greater precision, given sufficient clock stability in the subscriber stations, since an uncertainty in terms of timing of up to 0.5 x chip duration t_{chip} can occur with simple detection using a matched filter.

The transmission of the synchronous information in the uplink parallel to the transmission of user data is made more difficult by the fact that the synchronous information is a priori not known, or not known sufficiently precisely, as a result of which its acquisition would lead to an asynchronous interference situation with respect to the actual user data transmission. In order to avoid this, in each case only one item of synchronous information for all the

subscriber stations which are active in parallel is transmitted simultaneously in the delay time between the transmission cycle and reception cycle, as a result of which the time information can be detected more reliably because the transmission is subject to significantly less interference. For this purpose, if appropriate the delay time must be extended somewhat, but this is acceptable in order to achieve improved detection.
As a result of the transmission-end shifting of the symbols by one sample value in each case, but [lacuna] symbol-based matched filtering, with fixed timing, in the receiver of the base station, the time resolution or precision of the synchronization information within only one burst is improved up to a sample value t_{sample}, which, in the case of conventional detection, can be up to 0.5 x chip duration t_{chip}.

In order to avoid data collisions, the radio base station transmits to the subscriber station via the central service channel a status signal specifying which subscriber stations are to transmit their synchronization sequence consecutively. After the evaluation of the signal transmit time by the radio base station, said station transmits via the service channel the subscriber-specific starting times for the uplink transmission.

In a further preferred refinement of the method, orthogonal gold sequences of the length of one symbol in each case are used for the code spreading of the data both in the uplink and in the downlink, said sequences being relatively easy to generate. Furthermore, the orthogonal gold sequences have defined cross-correlation properties, the result of which is the subscriber stations, in which the synchronization mechanism fails, do not cause any significant faults in the other parallel transmissions. Furthermore, in comparison with Walsh sequences and similar sequences, these have the advantage of a uniform spectral power distribution, which is significant in particular in the case of short sequences.

It is advantageous for the design of cellular structures if all the radio base stations which lie in the range of mutual radio influence are synchronized in terms of the transmission/reception cycle. In particular radio base stations or subscriber stations which are in line-of-sight with respect to one another owing to an exposed geographical position could otherwise give rise to considerable interference at the receivers of the respective other radio cells. The synchronization may be carried out, for example, by means of GPS or beacon signals which are passed on within the radio network.

The method can be particularly advantageously implemented in wireless local loop systems, since in these systems the stationary nature of the subscriber stations with relatively small changes of the properties of the radio channel over time can be exploited.

INS A5

The invention is explained in more detail below with reference to a preferred exemplary embodiment.

Fig. 1 shows a signal profile of a transmission in the downlink for a subscriber station,

Fig. 2 shows a signal profile of a transmission in the downlink for n subscriber stations,

Fig. 3 shows a schematic signal profile at the output of a matched filter in a subscriber station,

Fig. 4 shows an illustration of the polling method for the synchronization in the uplink,

Fig. 5 shows a structure of an uplink synchronization sequence,

Fig. 6 shows a detailed illustration of the structure according to Fig. 5, and

Fig. 7 shows a schematic signal profile at the output of a matched filter of a radio base station.

INS A6

Fig. 1 illustrates a schematic signal profile of a transmission of a radio base station to a subscriber

station over time t. The signal comprises a preamble 1 and a data item 2 which are transmitted with an amplitude P_T. The preamble 1 is in this case a radio-system-specific maximum sequence or gold sequence which is generated by the radio base station. The data item 2 constitutes the actual user data for the subscriber station. Since the information is transmitted for the purpose of direct subscriber-specific system control in a central service channel, a common preamble 1 can be used for all the subscriber stations.

Fig. 2 illustrates the signal profile of the transmission in the downlink for all n subscriber stations. Since the radio base station transmits simultaneously to all n subscriber stations, a corresponding superimposition of the signal profiles occurs. Owing to the transmission of a common preamble 1 for all the subscriber stations into a service channel, a coherent addition occurs and the amplitude is $P_1 \sim n^2 P_T$. The superimposition of the user data takes place in accordance with the code modulation which is used, and varies correspondingly in amplitude, on average approximately the following is true $P_2 \sim nP_T$.

Sub A7 In order to determine a first item of synchronization information, the preamble 1 which is received by each subscriber station is fed a matched filter [sic] by means of which the reception quality can be determined. A typical signal profile at the output of the matched filter of a subscriber station is illustrated in Fig. 3. In order to determine the reception time of the transmission from the radio base station to the respective subscriber station, the output signal at the matched filter is evaluated by means of an amplitude threshold value switch. If the output signal exceeds a predefinable threshold Tr1, the amplitude threshold value switch produces a trigger signal, that [sic] represents the starting time for the reception of the preamble.

Fig. 4 illustrates the signal profiles for the synchronization in the uplink. In order to avoid inter-

ference, the transmission of synchronization sequences 3 by the individual subscriber stations takes place here in the form of a polling method, i.e. in the first burst only the first subscriber station transmits its synchronization sequence 3 to the radio base station. Subsequently, all n subscriber stations then transmit their user data 4 simultaneously to the radio base station. In the second burst, only the second subscriber station then transmits its synchronization sequence 3, until finally in the n-th burst the n-th subscriber station transmits its synchronization sequence 3.

A more precise structure of the synchronization sequence 3 is illustrated in Fig. 5. The synchronization sequence 3 comprises, for example, four identical symbols 5 which are transmitted successively, the distance between the symbols 5 being increased successively by one clock pulse t_{sample} of the system clock, and the first symbol 5 serving as preamble.

An exemplary profile of a symbol 5 is illustrated in Fig. 6, and it corresponds to the second symbol 5 with the transition to the third symbol 5 according to Fig. 5.

Figure 7 illustrates an exemplary signal profile at the output of a matched filter in the radio base station when a synchronization sequence 3 according to Fig. 5 is received. Here, each of the four symbols 5 produces an output signal with an amplitude P which is larger than a predefined threshold value Tr2 of a downstream amplitude threshold value switch. The first symbol 5 produces an output signal with the amplitude Pb. The second symbol 5 which is transmitted directly after the first symbol 5 also produces an amplitude Pb. The third symbol 5 which is delayed by a system clock pulse t_{sample} produces an amplitude Pa, and the symbol 5 which is correspondingly delayed by 2 x t_{sample} produces an amplitude Pc. The optimum reception is therefore that of the third symbol 5 so that the signal transit time has to be corrected correspondingly by one system clock pulse t_{sample}. In this way, the transit time between a

subscriber station and the radio base station can be determined with corresponding precision so that the synchronization can also be performed in the order of magnitude of t_{sample}.

List of reference numerals

1) Preamble
2) Data item
3) Synchronization sequence
4) User data
5) Symbol